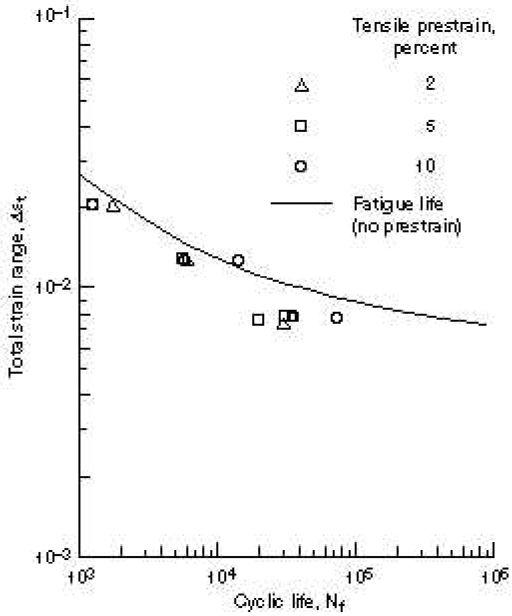
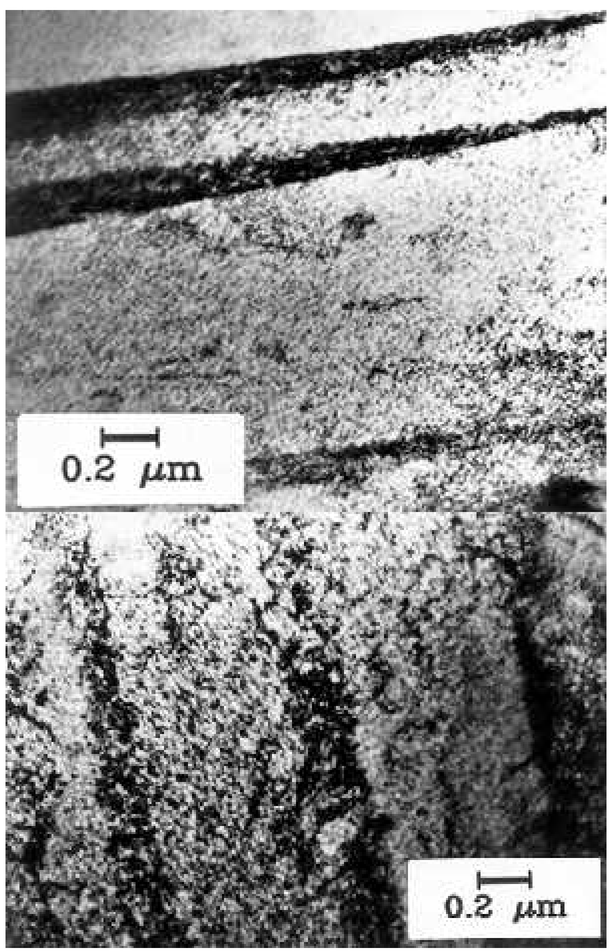
Fatigue Behavior and Deformation Mechanisms in Inconel 718 Superalloy Investigated

The nickel-base superalloy Inconel 718 (IN 718) is used as a structural material for a variety of components in the space shuttle main engine (SSME) and accounts for more than half of the total weight of this engine. IN 718 is the bill-of-material for the pressure vessels of nickel-hydrogen batteries for the space station. In the case of the space shuttle main engine, structural components are typically subjected to startup and shutdown load transients and occasional overloads in addition to high-frequency vibratory loads from routine operation. The nickel-hydrogen battery cells are prooftested before service and are subjected to fluctuating pressure loads during operation. In both of these applications, the structural material is subjected to a monotonic load initially, which is subsequently followed by fatigue. To assess the life of these structural components, it is necessary to determine the influence of a prior monotonic load on the subsequent fatigue life of the superalloy. An insight into the underlying deformation and damage mechanisms is also required to properly account for the interaction between the prior monotonic load and the subsequent fatigue loading.

An experimental investigation was conducted to establish the effect of prior monotonic straining on the subsequent fatigue behavior of wrought, double-aged, IN 718 at room temperature (ref. 1). First, monotonic strain tests and fully-reversed, strain-controlled fatigue tests were conducted on uniform-gage-section IN 718 specimens. Next, fully reversed fatigue tests were conducted under strain control on specimens that were monotonically strained in tension. Results from this investigation indicated that prior monotonic straining reduced the fatigue resistance of the superalloy particularly at the lowest strain range. Some of the tested specimens were sectioned and examined by transmission electron microscopy to reveal typical microstructures as well as the active deformation and damage mechanisms under each of the loading conditions (ref. 2). In monotonically strained specimens, deformation during the subsequent fatigue loading was mainly confined to the deformation bands initiated during the prior monotonic straining. This can cause dislocations to move more readily along the previously activated deformation bands and to pile up near grain boundaries, eventually making the grain boundaries susceptible to fatigue crack initiation. The mechanisms inferred from the microstructural investigation were extremely valuable in interpreting the influence of prior monotonic straining on the subsequent fatigue life of Inconel 718 superalloy.



Influence of prior monotonic straining on the subsequent fatigue of IN 718 superalloy.



Left (or top): Heavy localization of deformation in planar slip bands. IN 718 tested under *a monotonic tensile strain of 10 percent followed by fatigue at a strain range of 2 percent. Right (or bottom): Dislocation tangles within planar slip bands. IN 718 tested under a monotonic tensile strain of 10 percent followed by fatigue at a strain range of 0.8 percent.*

References

1. Kalluri, S.; Halford, G.R.; and McGaw, M.A.: Pre-Straining and Its Influence on Subsequent Fatigue Life. NASA TM-106881, 1995.

2. Kalluri, S., et al.: Deformation and Damage Mechanisms in Inconel 718 Superalloy. Superalloys 718, 625, 706 and Various Derivatives. E.A. Loria, ed., The Minerals, Metals & Materials Society, Warrendale, PA, 1994, pp. 593-606.